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Intake and digestion of wheat forage by stocker calves and lambs¹

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ABSTRACT: Because wheat forage contains high concentrations of N, NPN, digestible DM, and water, beef cattle and sheep require an adaptation period before positive BW are seen. The objective of the present experiment was to determine the impact of length of exposure of lambs and steers to wheat forage on BW gains, N retention, and forage digestibility. Sixteen steer calves (average BW = 210 ± 12 kg) and 20 wether lambs (average BW = 31.5 ± 2.0 kg) were randomly assigned to 1 of 2 treatment groups. Group 1 grazed a wheat pasture for 120 d during the winter, whereas group 2 was wintered on dormant warm-season grass pastures plus warm-season grass hay and plant-based protein supplements. In the spring (April 5), all lambs and steers grazed wheat pasture for 14 d and were then housed in metabolism stalls and fed freshly har-

vested wheat forage to determine forage digestibility and N metabolism. Data were analyzed for lambs and steers separately as a completely randomized design, using the individual animal as the experimental unit. Lambs and steers grazing wheat pasture for the first time in the spring had less ADG during the first 14 d than lambs (80 vs. 270 g, respectively; $P = 0.01$) and steers (1.06 vs. 1.83 kg, respectively; $P = 0.09$) that had grazed wheat pastures all winter. Digestibility of DM, NDF, and ADF fractions and N metabolism of freshly harvested wheat forage by lambs and steers were not different ($P > 0.10$) between the 2 treatment groups. Less ADG during the first 14 d of wheat pasture grazing is most likely the result of less DMI by nonadapted animals and is not due to diet digestibility or N metabolism.

Key words: adaptation, digestion, intake, stocker, wheat pasture

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INTRODUCTION

More than 9 million ha of winter wheat are planted in the southern Great Plains each fall, and the majority of these hectares are grazed by calves and lambs (Peel, 2003). The cyclic pattern of winter wheat forage production dictates that the stocking rate used in the fall and winter will be less than the stocking rate in the spring (Phillips et al., 1996; Phillips and Albers, 1999). To have enough animals available in the spring to increase the stocking rate quickly, livestock managers purchase additional stockers in the fall and background them on dormant warm-season grasses plus supplemental hay and protein until needed (Phillips et al., 2004). Because dormant warm-season grasses are low in energy and CP content, ADG is often restricted to less than 25% of that observed for animals on wheat pasture (Phillips et al., 2004). Because winter ADG was

restricted, compensatory gain was anticipated in the spring when grazers were moved to spring wheat pasture. However, in these situations, compensatory gain was not observed in calves during the spring graze-out period, but compensatory growth was observed during the finishing phase immediately following spring graze-out (Phillips et al., 2001, 2004). Our failure to observe compensatory gain during the graze-out period may have been masked by a 7- to 14-d adaptation period at the beginning of the graze-out period, when animals gained very little BW (Phillips, 1986; Phillips et al., 2006). The objective of the present experiment was to determine the impact of long- and short-term exposure of stocker lambs and steers to wheat forage on forage DMI, digestibility, and N retention.

MATERIALS AND METHODS

This experiment was approved by the USDA-ARS Grazinglands Research Laboratory Animal Care and Use Committee, and all procedures followed the recommendations of the Consortium for Developing a Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (1988). Sixteen steer calves (average BW = 210 ± 12 kg) and 20 wether lambs

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(average BW = 31.5 ± 2.0 kg) were randomly selected from the research herd and flock at the USDA-ARS Grazinglands Research Laboratory (35°32' N 98°2' W). Steers were primarily British breed crosses, and lambs were Dorset \times Rambouillet crosses. Both steers and lambs were less than 1 yr of age at the beginning of the experiment and were randomly assigned to 1 of 2 treatment groups. The first group of animals was allowed to graze a single (3.0-ha) winter wheat pasture (*Triticum aestivum*, var. TAM101) for 120 d (December 5 to April 5). These steers and lambs were considered to be adapted (adapted group) to a diet of winter wheat forage before the initiation of the spring grazing season on April 5. The second group of steers and lambs was maintained on dormant warm-season grass pastures, was provided warm-season grass hay and plant-based protein supplement as needed to maintain an ADG of approximately 0.1 kg (lambs) and 0.5 kg (steers) for the 120-d winter stocker period (December 5 to April 5), and was considered to be nonadapted (nonadapted group) to winter wheat forage at the beginning of the spring grazing season. On April 5, all lambs and steers were placed on a 3-ha wheat pasture. Lambs and steers grazed wheat pasture for 14 d, then were housed in metabolism stalls and fed freshly harvested wheat forage for 12 d. Body weight was taken at the beginning and end of the winter grazing season and at the beginning of the metabolism study on d 14 of the spring graze-out period. All BW were recorded after an 18-h fast without feed and water.

In the metabolism study, steers and lambs were randomly assigned to metabolism stalls and allowed 7 d to adjust to the stalls. Feces and urine were collected daily for 5 d, weighed, and sampled to determine forage digestibility and N retention (Phillips and Pendlum, 1984; Phillips et al., 1995b). Digestibility was calculated by subtracting the amount excreted from the amount consumed and dividing by the amount consumed. During the 12-d metabolism trial, steers and lambs had ad libitum access to wheat forage that was harvested with a mechanical chopper at 0800 h each day. Each morning, wheat forage fed the previous day was removed, weighed, sampled for DM content, and replaced with fresh wheat forage. A sample of fresh wheat forage was taken daily and divided into 2 subsamples. One subsample was frozen and stored for later analysis to determine soluble N and NPN concentrations, and the other subsample was dried at 65°C for 72 h to determine DM content.

At the end of the metabolism study, ruminal samples were collected 2 h after feeding via stomach tube equipped with a metal strainer, and plasma samples were collected 6 h after feeding via jugular venipuncture. Ruminal ammonia concentration was determined by ion-specific electrode as described by Phillips (1983). Plasma glucose, urea-N, and total protein concentrations were determined colorimetrically (Sigma Chemical Co., St. Louis, MO). Samples of feed, orts, and feces taken for DM determination were analyzed for NDF

and ADF concentrations by using the method of Goering and Van Soest (1970). Total N of feed, orts, feces, and urine was determined by the Kjeldahl method (AOAC, 1984). The N content of the frozen wheat forage was fractionated into soluble N and NPN by blending 5 g of frozen forage with 200 mL of buffer (1.13 g of Na_2HPO_4 , 1.09 g of NaH_2PO_4 , 0.43 g of KCl, 0.43 g of NaCl, 0.06 g of MgSO_4 , 0.15 g of K_2SO_4), followed by an incubation period of 1 h at 39°C. The mixture was then filtered and the N concentration of the filtrates before (soluble N) and after (NPN) the addition of 10% sodium tungstate was determined by an ion-specific electrode (Ammonia Electrode Model 95-10, Orion Research Inc., Cambridge, MA; Phillips, 1986).

Initial BW and ADG during the winter and spring grazing periods, digestibility of DM, N, NDF, and ADF, and constituents of ruminal and plasma samples were analyzed within animal species as a completely randomized design by using the GLM procedure (SAS Inst. Inc., Cary, NC). Animal was used as the experimental unit. All data are presented as least squares means.

RESULTS AND DISCUSSION

Stocker Performance

Over the 120-d winter stocker period, animals assigned to graze winter wheat pasture (adapted) gained BW more rapidly ($P < 0.01$) than animals assigned to graze dormant warm-season pastures (nonadapted; Table 1). Stocker ADG observed during the winter grazing period in the present experiment fell within the range of those expected for steers and lambs grazing winter wheat pasture from November through March in central Oklahoma (Mader et al., 1983; Phillips, 1986; Gallavan et al., 1989). Phillips et al. (1991, 2001) reported that cattle grazing dormant warm-season grasses and provided supplemental feed gained less BW during the winter stocker period than cattle on winter wheat pasture because winter wheat pasture was higher in nutrient density than dormant warm-season grasses plus supplemental feed.

During the first 14 d of the spring grazing season, steers and lambs in the adapted group gained BW more rapidly ($P < 0.05$) than steers and lambs in the nonadapted group (Table 1). However, a portion of the observed differences in BW gain between the 2 treatment groups may be the result of differences in fill. Because calves grazing dormant warm-season grasses have greater fill than cattle grazing winter wheat, a reduction in fill in the nonadapted group would be anticipated once they are shifted from dormant warm-season pastures to wheat pasture (Choat et al., 2003; Phillips et al., 2006). Choat et al. (2003) determined that steers grazing dormant native warm-season pastures had twice the amount of fill (18 g of DM/kg of BW) as steers grazing wheat pasture (9 g of DM/kg of BW). In the present experiment, steers backgrounded on native warm-season pasture had a BW of 251 kg and a

calculated fill of 4.5 kg (18 g/kg of BW \times 251 kg of BW) when placed on wheat pasture in the spring. Shifting these grazers from native warm-season pastures to wheat pasture would result in a reduction of fill from 18 to 9 kg of DM/kg of BW, totaling a decrease of 2.26 kg in BW. During the first 14 d of the spring grazing period, steers in the adapted group gained 25 kg of BW, whereas steers in the nonadapted group gained only 13 kg. Of the 12-kg differential in BW gain between the adapted and nonadapted steers, we could attribute only 2.26 kg to lessening of fill with a shift in diet.

Previous research has shown that steers and lambs unfamiliar with wheat forage consume less forage and have reduced ADG (Lippke, 1986; Gallavan et al., 1989; Phillips and Von Tungeln, 1995). One explanation for the reduction in DMI would be an unstable ruminal environment. With a shift from poorly to highly digestible forages, ruminal function must adjust to changes in fermentable substrates (Lippke et al., 2000; Beck et al., 2005). We hypothesized that DMI during the first 14 d of wheat pasture grazing is controlled more by metabolic feedback than ruminal fill. The metabolic feedback could be provided by an increase in ruminal fermentation products or an increase in ruminal ammonia concentration resulting from dietary nutrient composition changes. Because the spring grazing season is less than 60 d in length, less ADG for a few days at the beginning of the spring grazing season could significantly reduce overall animal performance and diminish any compensatory gain that potentially occurs after grazers have adapted to the new diet.

Wheat Forage Chemical Composition

At the beginning of the winter grazing season, wheat forage contained $24 \pm 5.5\%$ DM and 31 ± 7.3 g of N/kg of DM. In previous work, we reported similar DM and N concentrations for wheat forage during the winter grazing season (Phillips et al., 1995a,b). As the wheat plant matures in the spring, N concentration decreases and NDF and ADF concentrations increase (Stewart et al., 1981; Mader et al., 1983; Phillips et al., 1995a). Based on chemical composition, BW gains during the first half of the spring grazing season would be greater than those in the last half. As a result, nonadapted lambs and steers may not exhibit compensatory gain during the last half of the grazing season because nutritional density is less (Lippke et al., 2000).

Wheat forage fed during the metabolism study had a DM concentration of $21.4 \pm 2.3\%$ and a nutrient density of 13.7 ± 0.12 g of N, 640 ± 25 g of NDF, and 372 ± 20 g of ADF/kg of DM. Of the total N, $79.1 \pm 4.6\%$ was soluble N and $45.7 \pm 2.0\%$ of the soluble N was in the form of NPN. Although the total N concentration of wheat forage used in this experiment was less than previously reported, the proportion of total N that was soluble N and NPN was greater than previously reported (Phillips et al., 1995b). In previous work at this laboratory,

Table 1. Initial BW, winter ADG (120 d), and spring ADG (14 d) of lambs and steers backgrounded on wheat pasture (adapted) or dormant warm-season grass (nonadapted) in the winter and wheat pasture in the spring

Item	Adapted	Nonadapted	SE	<i>P</i> <
Lambs				
Initial BW, kg	31.7	32.5	0.8	NS ¹
Winter ADG, ² kg	0.149	0.106	0.009	0.01
Spring ADG, ² kg	0.294	0.093	0.017	0.01
Steers				
Initial BW, kg	210	210	8	NS
Winter ADG, ² kg	0.73	0.34	0.08	0.01
Spring ADG, ² kg	1.82	0.90	0.29	0.01

¹Nonsignificant ($P > 0.10$).

²Winter ADG = December 5 to April 5; spring ADG = first 14 d of the grazing season, April 5 to 19.

we observed an increase in plasma N and protein and ruminal NPN and ammonia concentrations when heifers were allowed to graze wheat pastures in the spring (Phillips, 1986). Over time, these N metabolism indices decreased, indicating that heifers were adapting to the new N-rich diet. Therefore, nonadapted steers and lambs in the present experiment may have reduced DMI to limit N intake until the rumen could adapt to processing greater amounts of soluble N (Chalupa et al., 1964; Phillips, 1986).

The amount and form of N in wheat forage is influenced by the amount of N fertilizer applied and environmental factors such as air temperature, soil water concentration, and stage of plant maturity (Stewart et al., 1981; Gallavan et al., 1989). However, wheat forage NDF and ADF concentrations were similar to previous reports from this location (Vogel et al., 1989). Wheat forage DM is rapidly digested, but not as quickly as the N fraction. The N fraction in wheat forage is primarily a highly soluble, rapidly ruminally digested pool (Vogel, 1988). As a result, N is released at a faster rate than the synthesis of microbial protein. Excess ruminal N is absorbed and excreted or recycled, but increased plasma N levels may serve as a negative metabolic feedback signal that reduces DMI. Adapting animals to high dietary concentrations of N before grazing wheat pastures may decrease the wheat pasture adaptation period. Providing supplemental energy will increase ADG of steers grazing wheat pasture by increasing microbial growth and protein synthesis (Chalupa et al., 1964; McCollum and Horn, 1990; Horn et al., 1995). Providing supplemental energy sources during the transition period to wheat pasture may reduce ruminal ammonia concentration and increase wheat forage DMI.

Intake and Digestibility of Wheat Forage

The amount of freshly harvested wheat forage DM consumed by lambs in the adapted and nonadapted

Table 2. Digestibility of DM, N, NDF, and ADF and N metabolism of harvested wheat forage fed to lambs and steers that had been backgrounded on wheat pasture (adapted; A) or on dormant warm-season grass pasture (nonadapted; NA) before grazing wheat pasture in the spring

Item	Lambs				Steers			
	A	NA	SE	<i>P</i> <	A	NA	SE	<i>P</i> <
Digestibility, g/kg								
DM	618	636	10	0.22	646	622	10	0.13
N	586	619	12	0.06	627	592	15	0.14
NDF	605	627	16	0.37	638	619	13	0.34
ADF	587	608	19	0.41	627	607	14	0.35
N intake, g/kg of BW ^{0.75}	0.434	0.529	0.024	0.02	1.04	1.09	0.35	0.34
N retention								
g/kg of BW ^{0.75}	-0.050	0.020	0.020	0.02	0.207	0.303	0.025	0.02
% of N intake	-45.8	3.20	48.1	0.21	19.8	27.9	2.2	0.02
% of N absorbed	-84.3	4.96	86.3	0.20	31.5	46.7	3.2	0.01

groups (613 vs. 675 g/d; SE = 36, respectively) did not differ ($P = 0.25$). When DMI was expressed as g/kg of BW^{0.75}, lambs in the nonadapted group consumed more ($P = 0.02$) DM than lambs in the adapted group (39.2 vs. 32.3 g/kg of BW^{0.75}; SE = 1.8, respectively). Dry matter intake by lambs in the present experiment was approximately one-half of previously reported values using the same facilities (Phillips et al., 1995b). However, Gallavan et al. (1989) reported similar DMI (680 g/d) for lambs of similar BW and fed freshly harvested wheat forage; they also observed an increase in weekly DMI as forage DM concentration increased. From those data, they concluded that lambs were sensitive to wheat forage DM concentration and that forage DM concentration must be >17% for DMI to exceed 40 g of DM/kg of BW^{0.75}. We concluded that low forage DM concentration may have limited DMI during the metabolism study.

Dry matter intake by steers of freshly harvested wheat forage was 2.6% of BW during the metabolism study. Steers in the adapted group had greater ($P = 0.06$) DMI than steers in the nonadapted group (5,840 vs. 5,180 g/d; SE = 139, respectively). As observed in the lambs, when DMI was expressed as grams of DM per kilogram of BW^{0.75}, DMI was greater ($P = 0.03$) for the steers in the nonadapted group as compared with steers in the adapted group (79.6 vs. 76.0; SE = 2.5, respectively). Our observations were in the lower range of previously reported DMI (2.3 to 4.0% of BW) for steers grazing wheat pasture (Andersen and Horn, 1987; Vogel et al., 1989) but were greater than previous reports for steers in metabolism stalls (Phillips and Pendulum, 1984).

Ingestive behavior is different between calves and lambs when sward characteristics are varied, and lambs are more sensitive to sward conditions than calves (Hodgson, 1981; Forbes, 1986). In the present experiment, freshly harvested wheat forage was presented daily, which negated any sward effects. Lambs and steers vary in their capacity to digest low-quality

forages, but not high-quality forages such as wheat forage (Prigge et al., 1984). However steers have greater ruminal volume than lambs (0.76 vs. 0.53 L/BW^{0.75}, respectively; Prigge et al., 1984), which might explain why lambs are more sensitive than steers to DM concentration of wheat forage.

Body weight at the beginning of the metabolism trial was greater ($P < 0.01$) for lambs and steers in the adapted group as compared with lambs (53.4 vs. 45.9 kg, respectively) and steers (326 vs. 262 kg, respectively) in the nonadapted group. Hersom et al. (2004) reported that under similar conditions, steers restricted in growth during the winter by grazing dormant native pastures had less BW, but had similar daily DMI when nutrient restriction was removed as compared with steers grazing wheat pasture during the winter. They also observed that when DMI was expressed as a percentage of BW, it was greater for the steers that had been previously restricted in growth. Therefore, for steers and lambs to express compensatory gain during the spring grazing season, daily DMI (g/kg of BW) must be greater than that for nonrestricted steers and lambs.

When lambs are restricted in growth, internal organ weight and the amount of energy needed for maintenance are reduced (Kabbali et al., 1992; Fluharty and McClure, 1997; Fluharty et al., 1999). As a result, when previously restricted lambs are fed a higher energy diet, more energy is available for gain (Sainz et al., 1995). Greater DMI and lower maintenance costs could account for greater rates of BW gain in cattle and sheep that have previously been restricted in growth.

Digestibility of DM, NDF, and ADF fractions of freshly harvested wheat forage by lambs and steers did not differ ($P > 0.10$) between the 2 treatment groups (Table 2). However, lambs in the nonadapted group had greater ($P = 0.06$) apparent N digestibility than lambs in the adapted group (Table 2). Lambs in the nonadapted group consumed more ($P = 0.02$) N than lambs in the adapted group and were also in positive

Table 3. Ruminal ammonia, plasma glucose, plasma protein, and urea-N concentrations in lambs and steers that had been backgrounded on wheat pasture (adapted; A) or on dormant warm-season grass pasture (nonadapted; NA) before grazing wheat pasture in the spring

Item, mg/dL	Lambs				Steers			
	A	NA	SE	<i>P</i> <	A	NA	SE	<i>P</i> <
Ruminal ammonia	12	12	1	0.80	8	7	1	0.50
Glucose	78	73	3	0.40	100	94	3	0.15
Protein	6.8	6.7	0.1	0.40	6.7	6.3	0.1	0.06
Urea-N	11.0	12.0	1.0	0.80	5	4	0.3	0.17

N balance (Table 2). However, DMI of freshly harvested wheat forage was near maintenance level for both groups of lambs. Nonadapted steers also had greater ($P = 0.02$) N retention than adapted steers, but both adapted and nonadapted steers were in positive N balance (Table 2). Ruminal ammonia, plasma glucose, and urea-N concentrations were not different between adapted and nonadapted lambs or steers, but steers in the nonadapted group had a lower ($P = 0.06$) concentration of plasma protein than steers in the adapted group (Table 3). Ruminal ammonia, plasma protein, and plasma urea-N concentrations observed in this experiment are lower than those reported by Phillips (1986) and Appeddu et al. (2003). Calves used in those experiments grazed wheat pasture that had a much greater concentration of CP than the wheat forage fed in the metabolism study in the present experiment. Greater dietary concentration of CP would increase ruminal ammonia, plasma protein, and plasma urea-N concentrations. However, our observations agree with previous reports for stocker calves consuming a typical growing diet that has a balance of protein and energy concentrations (Phillips et al., 1986, 1991). On the basis of these observations, we concluded that after 14 d of grazing wheat pasture and 7 d of being fed freshly harvested wheat forage, the lambs and steers in the nonadapted group were digesting and metabolizing N as efficiently as the lambs and steers in the adapted group.

From the present experiment, we concluded that stocker steers and lambs backgrounded on native pastures during the winter and abruptly shifted to wheat pasture in the spring gained BW at a lesser rate than steers and lambs backgrounded on wheat during the winter. Changes in gastrointestinal tract fill occur when steers and lambs are shifted from a low nutrient density diet, such as dormant native pasture, to a high nutrient density diet, such as spring wheat forage, but the changes in gastrointestinal tract fill account for only a small portion of the total weight change observed. On the basis of observations made from d 21 to 25 of the spring grazing season, we concluded that digestibility coefficients were similar between long- and short-term wheat pasture grazers. Therefore, lower forage DMI was probably the major factor in lessening BW gains early in the spring grazing season. Transi-

tion diets could facilitate metabolic and ruminal adjustments that steers and lambs backgrounded on low nutrient density diets must make before fully utilizing spring wheat forage. Because the spring wheat grazing season may span only 60 d, increasing forage DMI and ADG during the first 21 d would greatly increase total BW gain during the spring. In addition, management strategies to shorten the adaptation period when stockers are placed on spring wheat pasture would allow grazers previously restricted in ADG by a low nutrient density diet to express compensatory gain during the spring grazing season.

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